Advances in Technology at the National Renewable Energy Laboratory

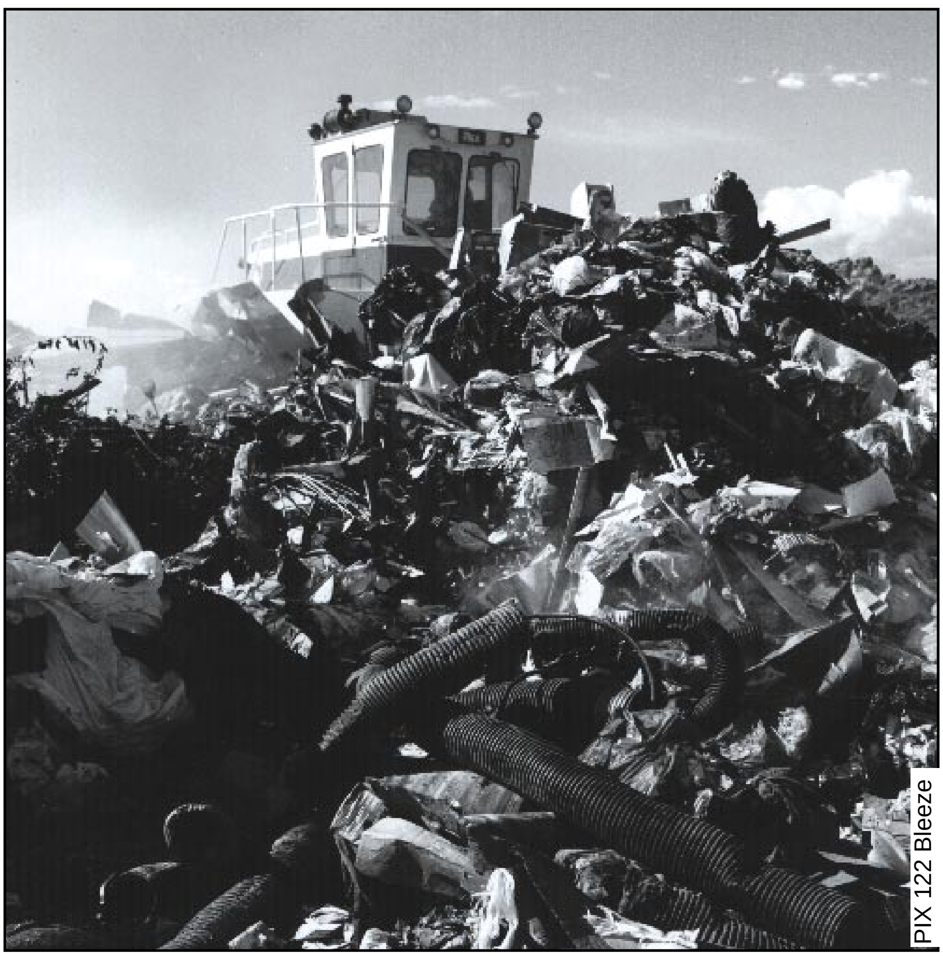
Technology Brief

Trash to Treasure

NREL's High-Solids Digester Converts Wastes to Biogas and Compost

We often picture tropical islands as being carefree, but by no means are they free from natural resource constraints and waste disposal problems. American Samoa is a case in point, with island residents depending on imported oil for virtually all their energy needs. And serious disposal challenges are posed by the wastes from the island's major industry, tuna canning, and the garbage discarded by its residents. But with a single technology developed by the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy, help with these problems is on the way.

NREL's high-solids digester (HSD) uses microorganisms that occur naturally in waste materials to turn those wastes into useful products—biogas fuel and high-quality compost. HSD works best with a mixture of waste types: fibrous (cellulosic) waste such as that found in municipal trash, combined with oily or fatty wastes such as tuna sludge from cannery processing. The biogas produced will fuel electrical generation, reducing American Samoa's need for imported oil. The compost is rich in organic fiber material and has little odor. With the nutrients contributed by the tuna sludge, the compost will be a valuable addition to the spartan volcanic soil of Samoa.



PIX 122 Bleeze

NREL's innovative high-solids digester could turn America's garbage into methane (natural gas) at a profit, providing an alternative to landfill burial.

Higher Solids = Lower Costs

Fermentation or digestion of organic material into more useful or less troublesome forms is not new. The backyard compost pile and the sewage treatment plant both serve this purpose. The HSD combines elements of both processes to economically turn wastes into compost and biogas fuel. The biogas is about 55% methane—the principal component of natural gas—and about 45% carbon dioxide.

Many sewage treatment plants use microorganisms in an anaerobic (without oxygen) environment to digest solid wastes. These plants generate methane gas, but only in modest amounts. When NREL scientists designed a reactor capable of mixing waste slurries that have a higher solids content (more like the compost pile), they were able to produce much higher volumes of methane gas.

At solids concentrations close to 35%, the HSD produces up to 10 times as much gas per unit of tank volume as do conventional “wet” or low-solids reactors that cannot handle more than 10% solids. The HSD can also process more organic material per day than can conventional reactors. This feature, combined with the substantially lower water requirement, allows HSD reactors to process as much waste as do conventional reactors 20 times their size.

The smaller reactor size reduces capital costs, and the lower water use reduces operating costs for effluent treatment and compost dewatering. Together with the greater volume of gas generated, these factors make HSDs more economically attractive than low-solids digesters. Municipal landfill operators and industrial waste managers should find that the HSD compares very favorably with incineration, waste-to-energy combustion, composting, and other waste treatments.

Nowhere to Go

Sanitary landfills are increasingly expensive and closely regulated. Many are now closing before new, still more stringent regulations go into effect. Local governments and landfill operators will want to extend the life of those landfills that do not close. When looking for ways to reduce incoming wastes, operators are likely to look to their industrial contributors to possibly take care of their own waste.

Although Samoa is currently exempt, ocean dumping of wastes such as tuna sludge is generally prohibited in U.S. waters. Combustion of waste to produce energy (NREL is developing some very promising technologies in this area) does provide a feasible alternative. But even though air emissions are very carefully regulated and controlled, combustion often encounters strong public concern that can make implementation difficult in many situations.

NREL’s high-solids digester may be the answer for many industries with specialized solid wastes. Food processing and other industries often have both cellulosic and fatty waste streams. Opportunities for cooperative projects with local government or other industries are sure to be plentiful.

Higher Solids = Faster Rates

Suspecting that conversion of cellulose to sugar was the rate-limiting step (hemicellulose breaks down very quickly in the HSD), NREL researchers developed methods to extract the cellulase enzymes that catalyze the cellulose conversion. That breakthrough enabled them to determine that the key factor for increasing fermentation rates is increasing contact between the cellulase enzyme and the cellulose. High liquid content simply reduces the amount of that contact; so increasing the solid content increases contact and fermentation rates.

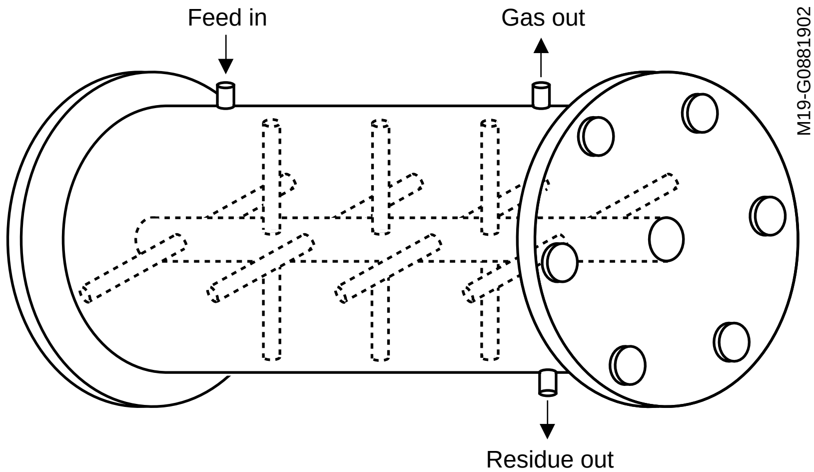

PIX 105 Gretz

NREL researcher adjusts the agitator-shaft seal of a 1-cubic-meter (1-m^3) high-solids digester (HSD). Because they process more material in a smaller volume of water, HSDs can match the capacity of conventional digesters more than 20 times their size.

More Fat = More Biogas

NREL researchers also discovered that the microorganisms grow rapidly on substrate materials that are high in fat, oil, or grease (FOG). When mixed with cellulosic material, FOG material increases the activity of the microorganisms on that material as well, resulting in faster processing on a sustained basis. Final methane concentration also increases by approximately 10% when FOGs are added. Because FOG waste streams are common and their disposal is often troublesome, there should be excellent opportunities to mix cellulosic and FOG waste materials for high-solids digestion.

Unique Design Promotes Efficient Digestion



The secret to the success of the NREL HSD lies in its horizontal design. Standard reactors use a cylindrical vessel with a vertical turbine or propeller shaft that rotates at about 100 revolutions per minute (rpm).

The HSD also uses a cylindrical reactor, but both the reactor and the agitator shaft are horizontal. Without the pressure on the material near the bottom of a vertical cylinder exerted by the weight of all the overlying material, mixing dynamics are quite different. The horizontal HSD is able to gently and thoroughly mix much drier material at speeds of less than 1 rpm. This greatly reduces mixing power requirements.

Typically the HSD uses four rows of rods that protrude radially from the centered agitator shaft. The rows of rods are equally spaced around the shaft, but the rods are staggered from one row to the next so that they sweep paths distinct from those in the preceding row.

Lab Experience + Trial Run = Market Ready

The HSD now has a solid track record of performance in the laboratory. The move of the HSD to the tuna canneries in American Samoa will be a maiden voyage toward commercial use. The 1-m^3 (35-ft^3) laboratory tank will be scaled up to a 40-m^3 (1400-ft^3) pilot plant capable of processing 900 to 2700 kg (1 to 3 tons) per day. Full-size (871-m^3 or 31,000-ft^3) digester systems will be able to handle 60,000 kg (67 tons) per day. In American Samoa, 3 units will digest a total of more than 180,000 kg (200 tons) per day.

The pilot plant will be constructed in 1994 and pretested at Terminal Island, California (in Los Angeles Harbor). It will be run for 3 to 6 months using local sorted municipal solid waste (MSW) and tuna sludge from Pan-Pacific Fisheries, Inc., the last remaining tuna cannery in the United States. This “mainland” trial run will allow any necessary physical modifications to be made prior to the move to American Samoa. It will also produce operational data to allow for adjustments to the process.

The pilot plant will then be shipped to American Samoa, where it will be operated for about a year on sorted MSW from the local landfill and tuna waste from the Star-Kist and Van Camps Seafood canneries. After the trial run, the canneries and the Samoan Public Works Department should have all the information they need to build a full-size plant. The pilot plant will then return to NREL for trial runs with other wastes.

HSD + Your Waste = Useful Products

NREL welcomes interest from other industries or governments in building a second pilot plant. MSW presents a clear need and opportunity for the HSD, but the process may also adapt well to agricultural or forestry residues or food processing waste conversion. In the coming years, NREL plans to develop a “treatability center” with facilities to assay any waste material for possible HSD treatment. Scientists at the center will determine how well different materials can be digested. In addition, the center will have an economic model that can plug in local waste management costs, energy generation payments, and compost market prices to project actual net operation costs.

HSD technology could also benefit the sewage treatment business with which it shares roots. The untreated FOGs that sewage plants must skim off waste streams could be treated in an HSD. And NREL is patenting a “pretreatment” that allows HSDs to be effective on sewage sludge.

Just as there is considerable flexibility in the variety of wastes that can be used in the HSD, there are options for the resulting products. The biogas can be upgraded to pipeline-quality natural gas or converted to hydrogen or methanol for automotive fuel. Instead of being used for soil enrichment, the compost can be burned for process heat or as a boiler fuel for electrical generation. Or the HSD can be used to improve other fermentation processes and produce totally different products.

The challenges that face American Samoa are representative of the challenges facing all of us. With the HSD, the U.S. Department of Energy has responded to the particular needs of that island. HSD technology can also meet the specific needs of other industries or communities. NREL is eager to see HSD make inroads into the huge volumes of municipal (more than 180 million tonnes or 200 million tons), agricultural, forestry, and food processing wastes generated annually in the United States.


PIX 1324 Gretz

In coming years, NREL plans to develop a “treatability center” with facilities to assay any waste material for possible HSD treatment.

Publications

Overend, R.P.; Rivard, C.J. (1993). "Thermal and Biological Gasification." *Proceedings of the First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry; August 30-September 2, 1993, Burlington, Vermont.* NREL / CP-200-5678. Golden, CO: National Renewable Energy Laboratory; pp. 470-497.

Rivard, C.J. (1993). "Anaerobic Bioconversion of Municipal Solid Wastes Using a Novel High-Solids Reactor Design: Maximum Organic Loading Rate and Comparison with Low-Solids Reactor Systems." *Applied Biochemistry and Biotechnology*. (39 / 40); pp. 71-82.

Rivard, C.J. (1993). "Anaerobic Bioconversion of Municipal Solid Wastes: Effects of Total Solids Levels on Microbial Numbers and Hydrolytic Enzyme Activities." *Applied Biochemistry and Biotechnology*. (39 / 40); pp. 101-117.

Rivard, C.J. (1993). "Anaerobic Digestion as a Waste Disposal Option for American Samoa.” NREL / TP-422-5043. Golden, CO: National Renewable Energy Laboratory.

For More Information

General Information and other NREL Technology Briefs:
Technical Inquiry Service
(303) 275-4099

Technical Information on this NREL Project:
Chris Rivard
(303) 384-7631

NREL Business Information:
Technology Transfer Office
(303) 275-3008

The National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado 80401-3393, is a national laboratory of the U.S. Department of Energy (DOE), managed for DOE by the Midwest Research Institute

Produced by the Communications and MIS Branch for the Alternative Fuels and Industrial Technologies Divisions
NREL/MK-336-5683 4/94

Printed with a renewable source ink on paper containing at least 50% wastepaper